84594

The Nernst-Ettingshausen Effect in p-Type Gallium Arsenide

S/181/60/002/010/016/051
B019/B056

beginning at 600 - 800°K again makes $Q^{\perp}$ negative. Finally it is pointed out that the results obtained here may be explained by the modern theory of thermomagnetic effects. Furthermore, the results obtained make it possible to estimate the part played by acoustic vibrations of the lattice in scattering processes. There are 1 figure, 1 table, and 3 references: 2 Soviet and 1 US.

X

ASSOCIATION: Fiziko-tekhnicheskiy institut AN SSSR Leningrad (Institute of Physics and Technology of the AS USSR, Leningrad)

SUBMITTED: April 4, 1960

Card 2/2

86431

S/181/60/002/011/015/042
B006/B056

9.4300 (3203, 1043, 1143)

AUTHORS: Nasledov, D. N., Smirnova, N. N., and Tsarenkov, B. V.

TITLE: The Temperature Dependence of the Main Parameters of GaAs Point-contact Diodes

PERIODICAL: Fizika tverdogo tela, 1960, Vol. 2, No. 11, pp. 2762-2769

TEXT: The authors produced point-contact diodes from n-type GaAs single crystals (conductivity at room temperature: 15 - 30 $ohm^{-1} \cdot cm^{-1}$; concentration: $n_n = 5 \cdot 10^{16} - 10^{17} cm^{-3}$; mobility: $\mu_n \simeq 2000\ cm^2/v \cdot sec$), and first give a brief description of the production method. The volt-ampere characteristics of the GaAs diodes were measured within the range of -196 - +300°C (Figs. 1, 2), and the main parameters are given in Table 2. The oscilloscopic characteristics were recorded by a "characteriograph" described in Ref. 6. The direct branches of the volt-ampere characteristics are described by the empirical formula

$I_{dir} = I_0 \left\{ \exp \left[\frac{q(U_{dir} - I_{dir} r_s)}{\beta kT} \right] - 1 \right\}$. The factor $I_c \sim \exp(-\Delta E/kT)$ ($\Delta E \simeq 0.7$ ev); β is a dimensionless factor which decreases with rising

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The Temperature Dependence of the Main Parameters of GaAs Point-contact Diodes

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temperature (cf. Table 2); r_s is the internal series resistance of the diode, and U_{dir} is the direct voltage drop on the diode. The experimental results are shown in five diagrams. The direct current in the diode depends on recombination processes occurring in the volume-charge region, the base layer, and on the surface, and also on the ohmic resistance of the base layer. $I_{dir} = I_o exp(qU_o/\beta kT)$ and $I_{dir} \sim exp\left[(\Delta E - qU_o/\beta)/kT\right]$, where ΔE is the activation energy. An analysis of the statistical volt-ampere characteristics in the temperature range concerned showed that: 1) the temperature dependence of the differential conductivity at U_o, of the factor I_o in the empirical formula for the direct current and the reverse current at -1v is exponential in the range of 373-573°K; the exponents coincide; 2) β decreases with rising temperature and is greater than 2 at -196°C; 3) the section voltage decreases with increasing temperature; the temperature coefficient coincides with the temperature coefficient of the contact potential difference calculated for a symmetrical p-n junction, whereas the absolute value of U_{sec} is smaller than the calculated value of U_{calc}; 4) at a constant voltage, the direct current rises within the range of

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The Temperature Dependence of the Main Parameters of GaAs Point-contact Diodes

S/181/60/002/011/015/042
B006/B056

0 - 0.6 v with rising temperature. Within the range of 0.7 - 1 v it first increases, after which it drops , which is due to the temperature dependence of the internal series resistivity of the diode. There are 5 figures, 2 tables, and 9 references: 7 Soviet, 1 US, and 1 Australian.

ASSOCIATION: Fiziko-tekhnicheskiy institut AN SSSR Leningrad (Institute of Physics and Technology of the AS USSR, Leningrad)

SUBMITTED: June 9, 1960

Таблица 2

T, °C	I_0, a	β	r_s, ом 1	$U_{отс}$, в 2	$I_{пр.}$ (+1 в), a 3	$I_{обр.}$ (−1 в), a 4
−196	$2.5 \cdot 10^{-13}$	3.2	38	0.93	0.005	—
20	$3.6 \cdot 10^{-10}$	1.7	20	0.67	0.0185	$4.2 \cdot 10^{-8}$
300	$4 \cdot 10^{-5}$	1.55	29	0.34	0.0275	$1.8 \cdot 10^{-4}$

Legend to Table 2: 1) r_s expressed in ohms; 2) U_{sec} in v, I_{dir} at +1v in a; 4) I_{rev} at -1v in a.

Card 3/43

80227
S/076/60/034/04/18/042
B010/B009

5.2100

AUTHORS: Dorin, V. A., Nasledov, D. N., Tartakovskaya, F. M. (Leningrad)

TITLE: Preparation of a Titanium Dioxide Semiconductor on Titanium at Low Oxygen Pressures

PERIODICAL: Zhurnal fizicheskoy khimii, 1960, Vol. 34, No. 4, pp. 809 - 814

TEXT: The oxidation of titanium in a gaseous phase obtained by heating powdered titanium oxide was investigated. In this way a gaseous phase containing only small amounts of oxygen was obtained. Titanium foils (0.6 mm thick, 20 x 20 mm^2) with at most 0.06% C, 0.06% N_2, 0.5% Fe + Ni, and traces of Cu were oxidized. The titanium oxide powder was annealed at 800° for three hours prior to use. In the first series of experiments anatase powder was used, in the second, rutile powder. Working temperatures ranged from 700° to 1100°, the weight increase in the titanium foil undergoing oxidation was determined by weighing. In the first series of experiments the color of the oxide film was observed to change with temperature, i.e., at 650-800° the oxide is light gray, but changes into dark gray and, at temperatures above 850°, into dark blue. An X-ray analysis showed that at

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31758
S/058/61/000/011/016/025
A058/A101

24,7600 (1043,1454,1537)

AUTHORS: Yemel'yanenko, O. V., Nasledov, D. N.

TITLE: Comprehensive investigation of the mechanism of equilibrium electric conductivity in gallium arsenide

PERIODICAL: Referativnyy zhurnal. Fizika, no. 11, 1961, 232, abstract 11E435 ("Uch. zap. Kishinevsk. un-t", 1960, no. 50, 3-10)

TEXT: One and the same instrument was used to measure the conductivity σ, the Hall constant R, the differential thermo-emf α, and the longitudinal and transverse Nernst-Ettingshausen constants $Q_{\parallel}$ and $Q_{\perp}$. In this instrument a difference in temperatures is produced along a specimen and measured by thermo-couples, which are used as current feeds incident to measurement of σ and R. $Q_{\perp}$ is measured on Hall probes, while $Q_{\parallel}$ is measured on the same terminals as α. The instrument has a symmetric heater-cooler system, by virtue of which it is possible to vary the direction of the temperature gradient along the specimen and make the specimen undergo practically any temperature drop. The measured potential differences amount to no less than 10 μv; the sensitivity of the circuit is $\approx$0.3 μv. The principal error of the instrument is in the determina-

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31758
S/058/61/000/011/016 025
A058/A101

Comprehensive investigation of the mechanism ...

tion of the temperature differences ΔT of the ends of the specimen. Two n-type Ga-As specimens were investigated. Specimen size was 12 x 3 x 1 mm. The temperature was measured in the range 0° - 600°K. From the curves of R versus T it is evident that both specimens are in the region of impurity conduction. At high temperatures scattering by phonons plays an essential role, with decrease in temperature ($T < 300^{\circ}$ - 400°K) scattering by the ionized impurity increases.

E. Filippova

[Abstracter's note: Complete translation]

Card 2/2

30634
S/081/61/000/020/010/089
B144/B101

9,4174 (1043,1138,1482)

AUTHORS: Yemel'yanenko, O. V., Nasledov, D. N.

TITLE: Comprehensive investigation of the electrical-conductivity mechanism in gallium arsenide

PERIODICAL: Referativnyy zhurnal. Khimiya, no. 20, 1961, 33, abstract 20B229 (Uch. zap. Kishinevsk. un-t, v. 55, 1960, 3-10)

TEXT: The temperature dependences of the thermo-emf, of the constants of the Nernst-Ettingshausen effect, of the Hall constant and of the Hall mobility were studied in n-type GaAs samples. It has been established that in the range of medium temperatures (< 300 - 400°C) the scattering from impurity ions plays a fundamental role in n-type GaAs samples containing various amounts of impurities (electron concentration $3 \cdot 10^{16} - 3 \cdot 10^{18}$ cm^{-3}). [Abstracter's note: Complete translation.]

Card 1/1

24.7600
26.2532

40158
S/058/62/000/007/044/066
A061/A101

AUTHORS: Volokobinskaya, N. I., Galavanov, V. V., Nasledov, D. N.

TITLE: A study of galvanomagnetic phenomena in high-purity InSb

PERIODICAL: Referativnyy zhurnal, Fizika, no. 7, 1962, 30, abstract 7E229 (In collection: "Vopr. metallurgii i fiz. poluprovodnikov". Moscow, AN SSSR, 1961, 55 - 69)

TEXT: The conductivity (σ) and the Hall coefficient (R) have been studied in InSb of n-type and p-type conductivity and a carrier concentration of 10^{13} - 10^{16} cm^{-3} at temperatures (T) of 77 - 450°K and magnetic field intensities (H) of 50 - 25,000 oe. It is shown that R is independent of H in the region of intrinsic conductivity. The strong dependence of R on H in the transition region from impurity to intrinsic conductivity fits well the theory which allows for a great diversity of electron and hole mobilities in InSb. A strong dependence of σ and R on H has been discovered in the impurity region. In pure n-type specimens R diminishes by 3 to 8 times as H changes from 50 to 25,000 oe, and the change of σ in a 25,000-oe field amounts to 500 - 700%. It is noted that the high value of

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S/058/62/000/007/044/069
A061/A101

A study of galvanomagnetic...

these effects does not fit the theory which allows for the scattering of electrons from the lattice acoustical vibrations and from impurity ions. In p-type InSb the dependence of R on H can be explained by the scattering of holes from impurity ions. In p-type InSb specimens of highest purity two impurity levels with activation energies of 0.02 and 0.09 ev have been detected. The forbidden band width, determined from the R(T)-function, is equal to 0.26 ev.

V. Ivanov-Omskiy

[Abstracter's note: Complete translation]

Card 2/2

89701

9.4160 (also 1137)

S/139/61/000/001/009/018
E032/E514

AUTHORS: Nasledov, D. N. and Solov'yev, R. A.

TITLE: Rectifying Properties of the System Se-Dielectric-Au

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy, Fizika, 1961, No.1, pp.104-109

TEXT: The specimens were prepared follows. Selenium was deposited on a bismuth film supported by an aluminium base. A further layer of a dielectric was deposited on top of the selenium and the composite film was covered with a layer of gold. Altogether 20 different insulating materials were tried. All the specimens exhibited a rectifying effect, which in some cases was quite well defined. It was found that the rectifying effect occurs at the selenium-dielectric contact. Among the dielectrics used were shellac, polystyrene, quartz, Lac 51, Lac K-47 and others. It was found that the rectifying effect appeared at once and did not vary with time. The thickness of the barrier layer appeared to depend on the magnitude of the applied voltage, while temperature changes between -70 and +100°C did not have much effect on the characteristics of materials such as quartz Lac 51, Lac K-47 and other

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89701

Rectifying Properties of the S/139/61/000/001/009/018
E032/E514

stable dielectrics. In the case of shellac, the rectifying properties deteriorate rapidly at higher temperatures. The photo-emf was also measured using visible radiation of 4×10^4 lux. The radiation was admitted through the gold film. Maximum photo-emfs were obtained with shellac and a material described as МГМ-16 (MGM-16) (of the order of 15 mV). The present paper is a preliminary report, further information will be published later. There are 9 figures, 2 tables and 7 references: 2 Soviet and 5 non-Soviet.

ASSOCIATION: Leningradskiy politekhnicheskiy institut imeni M. I. Kalinina (Leningrad Polytechnical Institute imeni M. I. Kalinin)

SUBMITTED: June 2, 1960

Card 2/2

20084

S/105/61/000/003/001/001
B116/B206

9.4300 (and 1035, 1143, 1150)

AUTHORS: Nasledov, D. N. and Zotova, N. V.

TITLE: Instrument for measuring direct currents of up to 40 ka

PERIODICAL: Elektrichestvo, no. 3, 1961, 70-73

TEXT: This is the description of an instrument similar to those developed by the Siemens-Schuckert Plants in the Federal German Republic (Refs. 2,3). It was developed by the authors for the purpose of measuring direct currents of up to 40 ka with an error of measurement of about 0.7%. The instrument is based on measuring the magnetic-field strength, the field being produced by the direct current by means of Hall generators developed by the authors. These Hall generators are made from indium arsenide (semiconductor) (Ref. 1). The new instrument differs from those used in the USSR for measuring direct currents by the following facts: it can easily be placed on a conductor rail and measure the current in any section of the rail; the instrument has a millivoltmeter of the class of accuracy of 0.5 and a linear scale in the entire measuring range; the instrument indications do not depend on outside effects of

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20084

Instrument for measuring direct ... S/105/61/000/003/001/001
B116/B206

foreign magnetic fields, foreign steel masses etc; the instrument has a sufficiently low error of measurement; the indications do not depend on the temperature up to + 50°C (the lower limit is unrestricted); the measuring process and calibration of the instrument are very simple; the Hall generators used in the instrument are exchangeable and reliable; the instrument is not sensitive to overloads and consumes a maximum of 1.5 w. The basic circuit diagram for connecting the two Hall generators is shown in Fig. 1. The rails conducting the direct current to be measured are gripped by the steel yoke consisting of two U-shaped parts. The Hall generators are placed in the two air gaps formed between these parts. It is shown that the sum of the magnetic-field strengths H_1 and H_2 in the two gaps of the width l_1 and l_2 respectively will only be proportional to the measured current I, if $H_{Fe}\ l_{Fe} \ll I$. H_{Fe} is the magnetic-field strength along the path l_{Fe} in the steel. This condition is only fulfilled in a material with steep magnetization curve and narrow hysteresis loop. Such a material is cold rolled silicon sheet steel

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ХВП (KhVP), which shows a high saturation induction, making it possible to obtain great magnetic-field strengths in the air gaps The neglect of $H_{Fe}l_{Fe}$ in comparison to I is the only fault of this direct-current measuring method. The instrument is described in short with the aid of Fig. 2. The yoke is made from KhVP steel and consists of thin lamellas, in order to prevent heating owing to eddy currents. Between the two yoke parts there are very exactly machined calibrated copper cups. The yoke dimensions are: 114 x 87 x 30 cm. The surface of the recess for the rail is 37 x 34 cm. The air gap is 3 cm. The weight of the yoke is 1600 kg. The Hall generators were made from indium arsenide and showed a sensitivity of about 100 μv/ö. It was possible to reduce the potential drop at the Hall contacts to from 0.05 to 0.2 mv for H = 0. The control panel consists of two indicating instruments of precision class 0.5 (a milliammeter for measuring the control currents of both transmitters and a millivoltmeter calibrated in kiloampere) and a circuit for separate transmitter feeding, compensating the foreign emf and measuring the Hall emf. Each Hall generator has its own, accurately selected load resistance, since not only the Hall emf, but also the linearity of the scale depends on it.

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20084

Provision is made for a recording device to be added on the panel. Fig. 3 shows the basic circuit diagram of the panel. In this circuit the microammeter with the resistor connected in series serves as recording apparatus. The instrument scale is strictly linear for measurements of up to 40 ka and remains so up to 50 ka, if the air gap is increased to 4 cm. The great weight of the instrument is mentioned as a drawback. Experiments to reduce it have led to a reduction of the measuring accuracy At present the authors are developing a direct current measuring instrument for currents of up to 100 ka, based on the same principal described here. There are 6 figures and 3 references: 1 Soviet-bloc.

ASSOCIATION: Fiziko-tekhnicheskiy institut AN SSSR (Physicotechnical Institute of the AS USSR)

SUBMITTED: December 8, 1956

4

89286

S/181/61/003/001/025/042
B006/B056

24.7600 (1043,1158,1160)

AUTHORS: Agayev, Ya., Yemel'yanenko, O. V., and Nasledov, D. N.

TITLE: Investigation of the thermomagnetic Nernst-Ettingshausen effects in solid solutions of the InSb-AlSb system

PERIODICAL: Fizika tverdogo tela, v. 3, no. 1, 1961, 194-197

TEXT: Already in earlier papers (Refs. 1-3) the authors reported on studies made of the InSb-AlSb system; the first component is characterized by high carrier mobility, the second by a broad forbidden band. Electrical conductivity, Hall effect and change in resistance in a transverse magnetic field have already been studied; studies of this system were continued, and form the subject of the present report. The principal aim of further investigations was to explain the scattering mechanism of carriers in solid solutions (by means of the Nernst-Ettingshausen effect), and to obtain more exact data on carrier mobility. The measuring method is described in Ref. 4. Fig. 1 shows the temperature dependence of the transverse Nernst-Ettingshausen effect ($Q^{\perp}$) on the basis of several compositions. In the impurity region, the specimens had hole-type conductivity; at room

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S/181/61/003/001/025/042
B006/B056

Investigation of the thermomagnetic...

temperature the hole concentration of specimens 1 (InSb) was $3\cdot10^{15}$ cm^{-3}, and that of 2-4 was about $3\cdot10^{17}$ cm^{-3} (2: InSb·AlSb, 3: 2.5InSb·7.5AlSb, 4: AlSb). Measurements were carried out in magnetic fields of 7000 oe, specimen 1 at 1200 oe; (weak fields, $uH/c \ll 1$). The negative sign of the N-E effect in specimens 2-4 at low temperatures indicates that the carriers are scattered on impurity ions, as is natural for semiconductors of the $A^{III}B^{V}$ group. Also the nature of the temperature dependence of the Hall effect is in agreement with this fact. At low temperatures, InSb has a positive $Q^{\perp}$, which indicates that the carriers are scattered on acoustic lattice vibrations. Scattering by impurities is insignificant owing to the high purity of the specimen. Impurity conductivity is conserved in AlSb, and the scattering mechanism may be determined even at high temperatures. At $T > 350°K$, $Q^{\perp}$ is positive (carrier scattering by acoustic lattice vibrations), but also in the case of InSb the $Q^{\perp}(T)$ curve becomes positive within the region of intrinsic conductivity. This is possible in spite of the bipolar character of conductivity, because in InSb the electron-to-hole mobility ratio is high, and the forbidden-band width is low. In InSb·AlSb specimens, the part of the $Q^{\perp}(T)$ curves related to mixed conductivity is

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Investigation of the thermomagnetic... S/181/61/003/001/025/042
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shifted toward higher temperatures. In InSb, mixed conductivity begins at about 140°K; in InSb·AlSb, at about 280°K; and in the specimen containing 75% AlSb, at 500-550°K; in AlSb it does not occur at all. This may be explained by the increase in the forbidden-band width in the case of increasing AlSb content. As regards carrier mobility, it was found that in transition from InSb to AlSb hole mobility decreases. On the assumption that at low temperatures in specimens 2-4 only impurity ions act as scattering centers; the hole mobility may be calculated from the N-E effect. At 110°K, 140, 80 and 30 cm^2/v·sec was obtained for specimens 2, 3, and 4. These values are 2-3 times as high as those calculated from Hall effect and conductivity (under the same conditions); however, they appeared to be closer to the true values, because the N-E effect is not disturbed, e.g., by a crystalline structure. In any case, these values may be considered to be limits. Fig. 2 shows the temperature dependence of the longitudinal N-E effect ($Q^{\parallel}$), on InSb (1) and InSb·AlSb (2). The fact that $Q^{\parallel}_{max}$ of (1) surpasses $Q^{\parallel}_{max}$ of (2) by about 2 orders of magnitude (the same may be observed in the case of $Q^{\perp}$) is explained by the much higher mobility and the much higher mobility ratio. Results show that scattering on the

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Investigation of the thermomagnetic...

disordered structure of InSb-AlSb alloys is low. Carrier mobility may be increased by an increase of purity. There are 2 figures and 6 Soviet-bloc references.

ASSOCIATION: Leningradskiy fiziko-tekhnicheskiy institut AN SSSR imeni akad. A. F. Ioffe (Leningrad Institute of Physics and Technology AS USSR imeni Academician A. F. Ioffe)

SUBMITTED: June 22, 1960

Card 4/~~5~~ 4

89287

S/181/61/003/001/026/042
B102/B204

24.7700 (1043,1143,1469)

AUTHORS: Yemel'yanenko, O. V., Lagunova, T. S., and Nasledov, D. N.

TITLE: Impurity band in p- and n-type gallium arsenide crystals

PERIODICAL: Fizika tverdogo tela, v. 3, no. 1, 1961, 198-203

TEXT: The present paper is a continuation of an earlier paper (Ref. 1) in which high-impurity n- and p-type GaAs specimens have been examined. It had been found that, in these specimens, the carrier concentration does not change with decreasing temperature (from room temperature to 1.5 - 2°K), and also the electrical conductivity remains nearly constant. In n-type specimens, the activation energy of impurity levels was equal to zero because of the formation of an impurity band overlapping the conduction band, and the electron gas was degenerate. The effective mass of the holes in GaAs is a multiple of the electron mass. Here, data are given on measurements of the Hall constant and the electrical conductivity of p- and n-type GaAs specimens, which are discussed. The measuring method is described in Ref. 1. The specimens were produced from initial substances of high purity (99.99%); the characteristic properties of the

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Impurity band in p- and n-type...

various specimens are given in a table. The results of measurement are shown in Figs. 1 and 2. Within the entire range of measurement (2-600°K), the specimens were within the region of impurity conductivity. The temperature dependence of Hall constant electrical conductivity for p-type GaAs is shown in Fig. 1 and Fig. 2, respectively. In the latter, the slope of the curves is constant from 30 to 4.2°K (the apparent breaks are due to the change in scale). Ge, InSb, and other semiconductors show a similar course of the curves, which is explained on the basis of a hypothesis concerning the mobility in the impurity band (Phys.Rev. v.96, p. 1226 and v. 99, p. 400). Here, the existence of two types of carriers of the same sign is assumed: ordinary carriers in the conduction or valence band, and such of lower mobility in a band formed by overlapping impurity levels. The Hall constant R may be expressed as a function of concentration and mobilities of the two types of carriers (1,2): $R = a_r(u_1^2n_1 + u_2^2n_2)/(u_1n_1 + u_2n_2)^2$, where $n_1 + n_2$ = const; the constant r_a differs only little from unity. Figs. 3 and 4 show R(T) and σ(T) for n-type GaAs. The maxima of the R(T) curves may be explained either on the basis of the above formula for $u_1n_1 = u_2n_2$, or by a surface conduction

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Impurity band in p- and n-type...

effect. However, the latter cannot explain all the phenomena observed. The slope of the curves with $T < 30^{\circ}K$ depends on processes occurring in the impurity band, and at higher temperatures on carrier transitions from the impurity band to the conduction or valence bands. The width of the energy gap between acceptor levels and valence band may be calculated from the slope of the R(T) curves or (for pure specimens) from the formula $n_1 \sim \exp(-\Delta E_{gap}/kT)$. Both methods yielded similar results: $\Delta E_{gap} = 0.01 - 0.02$ ev. The gap between donor levels and conduction band was found to be even smaller. Some interesting results were obtained for conductivity; thus, the resistivity of n-type GaAs at low temperatures in a transverse magnetic field does not increase (as is otherwise the case in semiconductors) but decreases. At H = 5000 oe and at helium temperature, the resistivity decrease in some cases attains 0.6 - 0.7%; in the case of pure specimens (5300 oe), even 7.5%; and at 2.4°K, 11%. On p-type specimens, this effect was either very low or did not occur at all. The effect on n-type GaAs cannot be explained by theories available today. There are 5 figures, 1 table, and 4 references: 1 Soviet-bloc and 3 non-Soviet-bloc.

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S/181/61/003/001/026/042
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Impurity band in p- and n-type...

ASSOCIATION: Leningradskiy fiziko-tekhnicheskiy institut AN SSSR imeni akad. A. F. Ioffe (Leningrad Institute of Physics and Technology AS USSR imeni Academician A. F. Ioffe)

SUBMITTED: June 22, 1960

Legend to the table: 1) Number and type of conductivity of the specimen; 2) impurity, % by weight; 3) carrier concentration; 4) carrier mobility.

№ образцов и тип проводимости 1)	Примесь, вес. % 2)	Концентрация носителей тока $n = \frac{1}{eR}$, см$^{-3}$ 3)	Подвижность носителей тока $u = R\sigma$, см^2/в · сек. 4)
		$T = 300°$ K	
3 p	0.1 Cd	$1 \cdot 10^{19}$	75
4 p	0.01 Zn	$4.5 \cdot 10^{18}$	95
5 p	0.1 Cd	$1.5 \cdot 10^{18}$	140
6 p	0.05 Cd	$4 \cdot 10^{17}$	150
7 p	0.013 Cd	$1.5 \cdot 10^{17}$	220
8 p	0.001 Zn	$1 \cdot 10^{17}$	300
7 n	—	$4.5 \cdot 10^{17}$	3000
8 n	0.001 Se	$2.1 \cdot 10^{17}$	3300
9 n	—	$2.2 \cdot 10^{16}$	3200

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20802

9.4300 (1043,1143,1150)

S/181/61/003/003/029/030
B102/B205

26.2532

AUTHORS: Burdukov, Yu. M., Imenkov, A. N., Nasledov, D. N., and Tsarenkov, B. V.

TITLE: Alloyed GaAs junction diodes

PERIODICAL: Fizika tverdogo tela, v. 3, no. 3, 1961, 991-994

TEXT: This is the continuation of Refs. 1-9 which the authors published in FTT with the exception of Ref. 9 (C. T. Sah, R. N. Noyce, W. Shockley, Proc. IRE, 45, 9, 1228, 1957). The diodes studied were made from thin plates of n-type GaAs single crystals which had been grown by the method of Chokhral'skiy. Their resistivity was 0.02 ohm·cm, their electron concentration $\lesssim 10^{17}$ cm^{-3}, and their mobility 3500 cm^2/v·sec at room temperature. The p-n junction was obtained by introduction of molten zinc or from the eutectic Au-Zn alloy. Lead served as non-rectifying base contact. The area of the p-n junction was equal to S = 0.005 cm^2. The volt-ampere characteristics of such a diode at 25 and 300°C are shown in a figure. They were recorded by the "characteriograph" described in Ref. 10 (Tsarenkov, PTE, No. 2, 144,

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B102/B205

Alloyed GaAs ...

1960). The most important results were the following: 1) The direct branch of the diode characteristic at voltages below the cutoff voltage can be described by the formula $I_{dir} = I_o\left[\exp(qU_{dir}/\beta kT) - 1\right]$ (1). I_{dir} is the direct current density, U_{dir} the direct voltage drop on the diode, and β a dimensionless factor. I_o increases with rising temperature. Within the range of nitrogen temperatures to room temperature, $I_o(T)$ is a weak function (weaker than at higher temperatures). At room temperature, $I_o \simeq 10^{-8}-10^{-7}$ a/cm^2, and at 300°C, $I_o \simeq 10^{-5}-10^{-4}$ a/cm^2. β decreases with rising temperature within the range of -196-+300°C. At nitrogen temperatures, $\beta \simeq 7 - 12$; at room temperature, 2 - 3; and on a further change in temperature, it approaches a value $\lesssim 2$. The direct branches of the volt-ampere characteristics of several diodes have two exponential sections: $I'_{dir} = I_{o1}\exp(qU'_{dir}/\beta_1 kT)$ and $I''_{dir} = I_{o2}\exp(qU''_{dir}/\beta_2 kT)$; $U'_{dir} < U''_{dir}$, $I_{o1} \gg I_{o2}$, $\beta_1 > \beta_2$. I_{o1} and I_{o2} increase with temperature (I_{o2} faster than I_{o1}); at 200-300°C, $I_{o1} \simeq I_{o2}$, $\beta_1 \simeq \beta_2$. The occurrence of two

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Alloyed GaAs ... S/181/61/003/003/029/030
B102/B205

exponential sections of the direct branch is related to the surface properties of the diode. By a change of the composition of the etching agent, one of them disappears, and in formula (1) $I_0 \simeq I_{02}$ and $\beta \simeq \beta_2$. The existence of two sections and the disappearance of one section by surface treatment is ascribed to the fact that the surface of gallium arsenide has an inverse layer. The cutoff voltage of the direct branch is lower than the contact voltage calculated according to Shockley's junction theory, and drops with increasing temperature. The temperature coefficients of the two voltages are almost equal. The curvature G_s of the linear section of the direct branch calculated from the data of the diode with a base 0.5 mm thick amounted to $\sim 10^3$ a/v·cm^2. The differential resistance at zero voltage can be exactly calculated from the formula $R_0 = \beta kT/qI_0$. $R_0(T)$ is nearly inverse to $I_0(T)$. R_0 of diodes with two exponential sections of the direct branch is much smaller than R_0 of diodes with only one section. The reverse branch of the characteristics at voltages lower than the breakdown voltage can be described by the empirical formula $I_{rev} = AU^n_{rev}$, where $n \lessgtr 1$; I_{rev} increases with temperature. The breakdown voltage also increases with temperature, which is

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taken as an indication of the electric character of breakdown in low-voltage GaAs diodes. There are 1 figure and 11 references: 9 Soviet-bloc and 2 non-Soviet-bloc.

ASSOCIATION: Fiziko-tekhnicheskiy institut AN USSR Leningrad (Institute of Physics and Technology, AS USSR, Leningrad)

SUBMITTED: September 23, 1960

Legend to Fig.: Ordinate unit 4 ma, abscissa unit 1 v (left-hand diagrams) or 0.25 v (right-hand diagrams).

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22054
S/181/61/003/004/020/030
B102/B214

24.7700(1035,1143,1395,1469)

AUTHORS: Yemelyanenko, O. V., Kesamanly, F. P., and Nasledov, D. N.

TITLE: The dependence of the effective mass of the electron in n-type InSb on the carrier concentration

PERIODICAL: Fizika tverdogo tela, v. 3, no. 4, 1961, 1161 - 1163

TEXT: The authors give the results of a determination of the effective electron mass in InSb for different carrier concentrations. The determination was done by measuring the differential thermo-emf. The experimental apparatus has been described by the authors in an earlier paper (FTT, II, vyp. 7, 1494, 1960). The samples were prepared by fusing the components in a stoichiometric ratio. They had n-type conductivity, and a carrier concentration $n = 3 \cdot 10^{16}$ cm^{-3} (at room temperature). They were doped with selenium up to an impurity concentration of $2.5 \cdot 10^{19}$ cm^{-3}. The size of the samples was 1 x 3 x 10 mm. They were polycrystalline and sufficiently homogeneous. The differential thermo-emf can be expressed by the relation $\alpha = -\frac{k}{e}\left[\frac{r+2}{r+1}\frac{F\quad(\mu)}{F_r(\mu)} - \mu\right]$ (1), where r is the exponent in

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The dependence of the ....

the scattering law $l \sim \varepsilon^r$, ε the electron energy calculated from the bottom of the conduction band, l the electron mean free path; for the various kinds of scattering, r has the values 0, 1/2, 1, 3/2, 2; μ is the reduced Fermi level, and $F_r(\mu)$ the Fermi-Dirac integral. On the other hand the electron concentration in the conduction band is related to μ:

$$n = \left(\frac{m^*}{m}\right)^{3/2} \frac{4}{\sqrt{\pi}} \left(\frac{2\pi mkT}{h^2}\right)^{3/2} F_{1/2}(\bar{\mu}),$$

where m* is the effective mass of the conduction electron and m the mass of a free electron. From α and r one can determine μ, from which m* can be calculated by the last equation. Since the thermo-emf in each case is a function of the scattering mechanism, the m* values for all InSb samples were calculated for the two extreme r-values 0 and 2. These values are given in the table for $T = 300^\circ$K; so also the $\bar{\mu}$ values. If it is assumed that the scattering mechanism does not vary from sample to sample, the effective electron mass increases significantly with increasing electron concentration. In sample 3n which contains $2.5 \cdot 10^{19}$ electrons/cm^3, m*/m is three times as large as in the pure sample 18n. This result is independent of the r-value. The assump-

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The dependence of the ...

tion that the character of scattering in the samples is independent of the impurity concentration is not very exact. In diamond-type crystals, to which InSb belongs, the electrons are scattered by acoustic lattice vibrations (r=0) and impurity ions (r=2). The role played by the two processes is a function of the temperature, the electron and impurity concentrations, the degeneracy of the electron gas, etc. If the increasing role of lattice scattering with an increase of the carrier concentration is taken into account, the effective mass of the electrons increases with increasing carrier concentration even more rapidly. It can, therefore, be said that in degenerate n-type InSb the effective electron mass increases significantly with increasing carrier concentration. The authors thank V. V. Galavanov for making available the InSb samples. There are 1 figure, 1 table, and 5 references: 3 Soviet-bloc and 2 non-Soviet-bloc. The two references to English language publications read as follows: S. D. Smith, T. S. Moss, K. W. Taylor, J. Phys. Chem. Sol. 11, 131, 1959; W. G. Spitzer, H. Y. Fan, Phys. Rev. 106, 5, 882, 1957.

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The dependence of the ...

ASSOCIATION: Fiziko-tekhnicheskiy institut imeni akad. A. F. Ioffe AN SSSR Leningrad (Institute of Physics and Technology imeni Academician A. F. Ioffe, AS USSR, Leningrad); Institut fiziki AN AzSSR Baku (Institute of Physics, AS Azerbaydzhanskaya SSR, Baku)

SUBMITTED: August 11, 1960

Legend to the Table: 1) Sample, 2) α, μv/deg.

(1) Образец	n, см$^{-3}$	(2) α, мкв/град.	β		m^*/m	
			$r=0$	$r=2$	$r=0$	$r=2$
18 n	$3.0 \cdot 10^{18}$	308	−1.4	1.0	0.029	0.011
14 n	$1.3 \cdot 10^{17}$	220	−0.3	2.7	0.040	0.013
11 n	$9.0 \cdot 10^{17}$	102	2.4	7.7	0.048	0.017
6 n	$6.9 \cdot 10^{18}$	34	8.3	25.0	0.062	0.021
3 n	$2.5 \cdot 10^{19}$	23	12.3	37.0	0.098	0.033

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82055

S/181/61/003/004/021/030
B102/B202

24.7700 (1035, 1143, 1395, 1469)

AUTHORS: ..en Chih-ch'ao and Nasledov, D. N.

TITLE: Electrical and galvanomagnetic properties of n-type InSb at low temperatures

PERIODICAL: Fizika tverdogo tela, v. 3, no. 4, 1961, 1185-1193

TEXT: The conduction mechanism of n-type InSb at temperatures of liquid helium has so far not been investigated. Therefore, the present article is devoted to this subject. Besides, the properties of the impurity band are hardly explored, particularly because pure n-type InSb crystals do not exist. The authors studied the temperature dependence of electrical conductivity and Hall constant for impurity concentrations of 10^{15}-10^{12} cm^{-3}, as well as the change in resistivity at helium temperatures due to a magnetic field. The results show that, at helium temperatures, conduction in the impurity band plays a considerable role in specimens with an impurity concentration of the order of 10^{14} cm^{-3} or less. In this case, electron mobility is relatively high in weak magnetic fields and decreases rapidly with rising H. The results of the studies are illustrated graphically. Specimen 7n (the

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B102/B209

Electrical and ...

specimens are numbered from 1n to 7n) with a carrier concentration of $4.5 \cdot 10^{15}$ cm^{-3} did not show any temperature dependence of Hall constant (R) and electrical conductivity (σ) below the temperature of liquid nitrogen, which is explained by an overlap of impurity band and conduction band. 1n, 4n, and 5n with $n < 10^{14}$ cm^{-3} have R(T) and σ(T) curves whose shape is characteristic of separate bands. The slope of the $\log \sigma = f(1/T)$ curves becomes steeper with decreasing impurity concentration. The results indicate that in n-type InSb, the impurity band is not as marked as, for instance, in Ge or p-type InSb: The maxima of the R(T) curves are very weak, and the σ(T) curves drop more slowly than in the case of Ge or p-type InSb. Rσ attains a high value at helium temperatures, i.e., the electrons in the impurity band have a high mobility which equals about that in the conduction band. With a drop of temperature, Rσ decreases more slowly than in p-type InSb; at helium temperature, it lies between 10^3 and 10^5 $cm^2/v \cdot sec$. Also $\Delta\varrho/\varrho_0 = f(H)$ is graphically shown for the different cases studied. For specimens with $n < 10^{14}$ cm^{-3}, these functions differ considerably from those for specimens with $n \sim 10^{15}$. At low concentrations, oscillations of the resistance in a magnetic field were not observed. Specimens 1n and 6n exhibited negative $\Delta\varrho/\varrho_0$ values in a weak field at helium temperatures.

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Specimens 3n, 4n, and 5n with impurity concentrations of less than 10^{13} cm^{-3} had no negative $\Delta\varkappa/\varkappa_0$ values. Electron mobility in the impurity band decreases quickly with rising H. In a transverse H-field, specimens 7n, 8n, and 9n with impurity concentrations of about 10^{15} cm^{-3} showed resistivity oscillations, from which the electron concentrations were calculated and then compared with those calculated from R. Agreement was satisfactory. There are 8 figures, 1 table, and 3 references: 2 Soviet-bloc and 1 non-Soviet-bloc. The two most recent references to English-language publications read as follows: E. H. Putley, Proc. Phys. Soc. 73, 128, 1959; R. F. Broom, Proc. Phys. Soc. 71, 459, 1958.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. akad. A. F. Ioffe AN SSSR Leningrad (Institute of Physics and Technology imeni Academician A. F. Ioffe, AS USSR, Leningrad)

SUBMITTED: August 25, 1960 (initially) and November 3, 1960 (after revision)

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23113
S/181/61/003/005/018/042
B136/B201

9.4300 (1150,1151,1136)

AUTHORS: Lien Chin-ch'ao and Nasledov, D. N.

TITLE: Electrical and galvanomagnetic properties of p-type InSb crystals at low temperatures

PERIODICAL: Fizika tverdogo tela, v. 3, no. 5, 1961, 1458 - 1464

TEXT: While the behavior of Ge and Si at helium temperatures has been studied repeatedly, the conduction mechanism of p-type InSb crystals is as yet hardly known. Results available so far (Ref.2: H. Fritzsche, K. Lark-Horowitz, Phys. Rev., 99, 400, 1955; Ref.3: E. Putley, Proc. Phys. Soc., 73, 128, 1959) point to the existence of an impurity band. Crystals prepared here by zone smelting, 8·1.5·1.0 mm in size, and with carrier concentrations of 10^{13}-10^{15} cm^{-3} at nitrogen temperature were examined by means of cold-resisting soldered probes in the temperature range from liquid nitrogen to 1.7°K as to their conductivity and galvanomagnetic behavior. The concencentrations of carriers at 77°K were $1.2 \cdot 10^{13}$, $3.0 \cdot 10^{14}$, $1.9 \cdot 10^{15}$, $4.9 \cdot 10^{15}$, $5.1 \cdot 10^{14}$, $1.3 \cdot 10^{14}$, and $7.9 \cdot 10^{13}$ cm^{-3} for specimens P5, 3P, P6, 4P, 7P, 8P,

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Electrical and ...

and 9P, respectively. In specimens with an impurity concentration of 10^{14}-10^{15} cm^{-3}, resistivity and Hall coefficient R were found to attain a maximum and to drop abruptly thereupon; this is in agreement with data from Refs. 2,3. The ascent of the curves log R = f(1/T) gives the activation energy. The product $R\sigma$ in the specimens 4P, P6, and 3P (Table 1) grows slowly with dropping temperature, passes through a maximum, and then drops abruptly, whereas in the other specimens the character of the curves is basically the same but $R\sigma$ drops more rapidly with rising temperature. Since the conduction mechanism depends on both the acceptor and the donor concentrations, these concentrations were determined separately (using the law of mass action) in the region of impoverishment at helium temperatures, under which conditions all impurities may be regarded as being ionized, and the concentration difference $N_A - N_D$ depends upon the Hall coefficient. Table 1 gives the calculated values of acceptor and donor concentrations, and the activation energy for specimens 4P, P6, and 3P; the fact that the activation energy depends on the compensation of impurities was taken into account. The form of the curve log R = f(1/T) for specimen P5 (hole concen-

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tration, 10^{13} cm^{-3}) points to the presence of two different types of acceptors with activation energies E_1 and E_2; they appear in various temperature ranges. All acceptors are ionized at nitrogen temperature, and the difference between acceptor and donor concentrations ($N_1 + N_2 - N_D$) can, therefore, be detemined from R. The values N_1=2.3.10^{12}, N_2=2.24.10^{13}, and N_D=2.24.10^{13} cm^{-3} were found. The behavior of Ge, Si, and InSb at helium temperatures cannot be explained by the usual theory of semiconduction. In specimens 4P and P6, Rσ was 5 and 32 cm^2/v.• sec, respectively. The hole mobility μ_2 in the impurity band was assumed not to depend on temperature, whose concentration p_2 attains a saturation value, with rising temperature which is larger than the acceptor concentration.

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23113

Specimen	N_A, cm^{-3}	N_D, cm^{-3} from data according to $\log R = f(1/T)$	p_2, cm^{-3} (saturation value)
4P	$5.09 \cdot 10^{15}$	$1.16 \cdot 10^{14}$	$4.7 \cdot 10^{14}$
P 6	$1.97 \cdot 10^{15}$	$8.0 \cdot 10^{13}$	$6.6 \cdot 10^{13}$

This indicates that not all the holes reaching the impurity band contribute to conduction, and that, therefore, some experimental results on impurity conduction disagree with the usual concept. The activation energy of acceptors in p-type InSb amounts to $(7 - 9) \cdot 10^{-3}$ ev. The calculation of R as a function of 1/T yields values that are in good agreement with experimental ones. A thermal treatment that changes the properties of InSb strongly, causes the activation energy of acceptors to increase to $(1.4 - 1.6)\cdot 10^{-2}$ ev, while the concentration depends on the conditions of the thermal treatment. There are 5 figures, 2 tables, and 13 references: 1 Soviet-bloc and 12 non-Soviet-bloc. The most recent reference to English-language publications reads as follows: E. Putley, Proc. Phys. Soc., 73, 128, 1959.

ASSOCIATION: Fiziko-tekhnicheskiy institut imeni A. F. Ioffe AN SSSR Leningrad (Institute of Physics and Technology imeni A. F. Ioffe, AS USSR, Leningrad)

SUBMITTED: January 4, 1961

28080
S/181/61/003/009/012/039
B102/B138

24.3600 (1035, 1138, 1385)

AUTHORS: Zolotarev, V. F., and Nasledov, D. N.

TITLE: Noise of p-type indium antimonide in a magnetic field at room temperature

PERIODICAL: Fizika tverdogo tela, v. 3, no. 9, 1961, 2635 - 2639

TEXT: It has already (Refs. 1 - 4, see below) been found that the noise of photomagnetic effect is of the same order of magnitude as thermal noise. The authors studied the photomagnetic-effect and current noises in thin (8 - 10μ) InAs monocrystals in a transverse magnetic field. The acceptor concentration of the crystals was $5.10^{16}cm^{-1}$. A special preamplifier with an equivalent noise input resistance of only 8 ohms was designed for the measurements (Fig. 1). The main amplifier used was a type 28-ИМ (28-IM) with an input transformer removed for pass-band broadening. The noise voltage at the output was measured by means of an АН-1-50 (AN-1-50) analyzer. The output shunt of the analyzer had a capacitance of 1500μf. The measurements (H = 0-25,000 oe) indicated that the photomagnetic noises

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S/181/61/003/009/012/039
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Noise of p-type indium antimonide...

have a white spectrum. $U^2_{noise} = 4kTR f$, where R denotes the resistance of the specimen in the magnetic field. This formula has been experimentally verified several times. The specimens exhibited remarkable photomagnetic sensitivity, the noises, however, did not react to an illumination up to 0.1 w/cm^2 when heated to 800°C, i. e. the photonic noise signal was well below the thermal noise signal. Current-noise measurements showed that both the noise-versus-frequency and the noise-versus-current curves were, in shape, independent of magnetic field strength. The curves $\ln U_{noise} = g(\ln f)$ were parallel straight lines. For $f \gg 10$ kc/sec the current noise can be described by the relation $U^2_{cur} = \frac{AR^2 I^2}{f} \Delta f$; the constant A was of the order of $\cdot\,^{-10}$. The small deviations from this law observed were attributed to the effects of the contacts. The excess noise is due to conductivity fluctuations induced by fluctuations of the Fermi level. The relation between minority and majority carriers is important for that kind of

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Noise of p-type indium antimonide... B102/B138

noise, its amount being determined by the fluctuations of the majority carriers in the semiconductor. If the currents are of sufficient strength, the noise current reaches a sort of saturation, the cause of which has hitherto not been explained. There are 3 figures and 9 non-Soviet references. The four most recent references to the English-language publications read as follows: Ref. 1: S. J. Nicolosi. Electr. Eng., 21, 48, 1958. Ref. 2: P. Kruse. J. Appl. Phys., 30, no. 5, 770, 1959. Ref. 3: S. Kurnick. J. Appl. Phys., 27, no. 3, 278, 1956. Ref. 4: P. Kruse. Electronics, 33, no. 13, 62, 1960.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR Leningrad)

SUBMITTED: April 3, 1961

29688 S/181/61/003/010/010/036
B102/B108

9,4170 (1051,1035,1482)

AUTHORS: Galavanov, V. V., Kartuzova, I. A., and Nasledov, D. N.

TITLE: Measurement of the diffusion length of minority carriers in InSb

PERIODICAL: Fizika tverdogo tela, v. 3, no. 10, 1961, 2973 - 2980

TEXT: Since the characteristics of InSb infrared receivers depend considerably on the minority-carrier lifetime τ (or their diffusion length L), measurement of these quantities is of great interest. The authors used the Waldes method to determine L and τ in n- and p-type InSb single crystals having impurity concentrations between 10^{12} and 10^{16} cm^{-3}. L was determined by the Waldes light-probe method. For weak illumination intensities, when the collector photo-emf $V < kT/5e$ (e - electron charge), V is proportional to the light-induced minority carrier concentration. When the surface recombination rate is small, $V = V_0 \exp(-x/L)$ in the dark (x - distance from the illuminated region). This relation holds for one-dimensional geometry. In axisymmetric geometry $V = V_0 \exp(-x/L)/\sqrt{x}$. It was to be found experimentally which of these formulas has to be applied.

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B102/B108

Measurement of the diffusion...

The 0.2 - 2 mm thick test pieces were polished and then etched with CP-4A (SR-4A). They were placed in a vacuum cryostat with an NaCl window. The light inciding on the specimen was interrupted by an 800-cps chopper. A tungsten or phosphor-bronze point served as a collector contact; a 28-ИМ (28-IM) amplifier was used to measure the variable photo-emf on it. The measurements were made between 100 and 200°K. The carrier concentration in the specimens at 77°K was determined from the Hall effect, L was determined from the inclination of the straight line logV=f(x). τ was determined from $\tau = L^2/D$ where

$$D = D_p \frac{b\left(1+\frac{p_0}{n_0}\right)}{b+\frac{p_0}{n_0}}, \qquad (4)$$

$D_p = u_p kT/e$ being the hole diffusion coefficient, $b = u_n/u_p$, the mobility ratio, p_0 and n_0 the equilibrium concentrations. For intrinsic conductivity $D = 2bD_p/(b+1)$. In the case of impurity conductivity, $D = D_p$ for n-type, and $D = D_n = u_n kT/e$ for p-type specimens. The carrier concentration in the intrinsic-conductivity region of InSb is given by

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$n_i \approx 6\cdot10^{14}T^{3/2}\exp(-1510/T)$. The temperature dependence of τ can be seen in Fig. 4. When temperature drops from 170 to 120°K, τ decreases to less than one hundredth its value. In this range the temperature dependence of τ obeys the Shockley-Reed law. It is shown that the experimental curves $\tau = f(1/T)$ agree with the formula

$$\tau = \frac{2\tau_i n_i}{n_0 + p_0} = \frac{2\tau_i n_i}{\sqrt{4n_i^2 + N_{n,p}^2}}, \qquad (12)$$

which holds for a neutral crystal and radiative recombination. $N_{n,p}$ are the majority-carrier concentrations in an n- or p-type crystal in the region of impurity conductivity. $\tau = 2\tau_i n_i/N_{n,p}$ holds for the impurity-conductivity region ($n_i \ll N_{n,p}$). The straight line corresponding to Auger recombination is too steep. Results: (1) No correlation was found between L and the impurity concentration. (2) The data agree with the radiative-recombination theory for $b \approx 600 - 700$. (3) The difficulties arising in the interpretation of the results may be due to an inaccurate measurement of L and an inaccurate calculation of τ_i. There are 5 figures, 1 table, and 24 references: 9 Soviet and 15 non-Soviet. The three most recent refer-

X

ences to English-language publications read as follows: R. A. Laff, H. Y. Fan. Phys. Rev. 121, 53, 1961; R. T. Landsberg, A. R. Beattie. J. Phys. Chem. Sol., 8, 73, 1959; R. N. Zitter, A. J. Strauss, A.E.Attard. Phys. Rev., 115, 266, 1959.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: April 28, 1961

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Legend to the Table: (1) Number of the specimen, (2) voltage.

№ образца (1)	p_0, см$^{-3}$	n_0, см$^{-3}$	u_n, см²/в · сек.	u_p, см²/в · сек.	v (2)
13p1.4	$1.4 \cdot 10^{13}$	—	$9 \cdot 10^{4}$	$9 \cdot 10^{2}$	100
13p1	$1 \cdot 10^{13}$	—	$1.5 \cdot 10^{5}$	$3 \cdot 10^{3}$	50
15p5	$5 \cdot 10^{15}$	—	$2 \cdot 10^{5}$	$4 \cdot 10^{3}$	50
16p1	$1 \cdot 10^{16}$	—	$6 \cdot 10^{4}$	$2 \cdot 10^{3}$	30
12n2	—	$2 \cdot 10^{12}$	$7 \cdot 10^{4}$	10^{2}	700
13n2	—	$2 \cdot 10^{13}$	$2 \cdot 10^{5}$	$3 \cdot 10^{2}$	650
13n3	—	$3 \cdot 10^{13}$	$4.5 \cdot 10^{4}$	10^{3}	45
14n6	—	$6 \cdot 10^{14}$	$1.2 \cdot 10^{5}$	$2 \cdot 10^{3}$	60

24.2200 (1144, 1137, 1164, 1035)
24.4421

30775
S/181/61/003/011/008/056
B102/B138

AUTHORS: Zolotarev, V.F., and Nasledov, D. N.

TITLE: Photomagnetic effect in p-type InSb at room temperature

PERIODICAL: Fizika tverdogo tela, v. 3, no. 11, 1961, 3306-3313

TEXT: Photomagnetic effect (ph. m. e.) in p-type InSb was measured at room temperature and at impurity concentrations from $1.2\cdot10^{16}$ to $1.3\cdot10^{17}\,\mathrm{cm}^{-3}$ in fields of 600 to 16,000 oe. The photomagnetic e. m. f. was measured by means of a sensitive 28 ИМ (28IM) amplifier. The specimens were illuminated by a hot point (800°C) with an intensity of $I_0 = 8.10^{-3}$ w/cm^2. The light flux could be modulated sinusoidally with a frequency of 800 cps. The specimens, 0.6 · 2 · 6 mm^3 large, were etched with СР-4 (SR-4). The lux-volt characteristics were found to be linear between $8\cdot10^{-5}$ to $8\cdot10^{-3}$ w/cm^2 light intensity. From the straight lines $H^2/i_s^2 = f(H^2)$ the electron

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S/181/61/003/011/008/056
B102/B138

Photomagnetic effect in p-type ...

mobility was determined using the relation $\mu_{phm} = \sqrt{\frac{1+bc}{H_1^2}} \cdot 10^8$ cm^2/v·sec.

The values determined in this way differ from those calculated from R_0 and σ_0 (Hall coefficient and conductivity at room temperature), which are denoted as μ_e. In Fig. 3 the ratio μ_{phm}/μ_e is shown as a function of impurity concentration p_1 (acceptor concentration). All specimens showed a linear dependence of photomagnetic e. m. f. and H for weak fields. For thick specimens ($d \gg l_d$) the short-circuit current is given in Ref 5 here by

$$i_0 = (\mu_n + \mu_p)\frac{e l_d N c_0}{1 + \frac{s}{l_d}}. \qquad (6)$$

and the ambipolar-diffusion length by

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X

$$\Gamma_d = \frac{l_d(1+c)^{1/2}}{\left(\frac{1}{\varphi_n}+\frac{bc}{\varphi_p}\right)^{1/2}} \qquad (7)$$

if the relaxation time is energy-dependent. If it is not,

$$I_s = \left(1+\frac{1}{b}\right)\frac{e I_0 \tilde{\mu} H \Gamma_d}{1+\frac{s_1\tau}{\Gamma_d}}, \qquad (1)$$

and

$$\Gamma_d = \frac{l_d(1+c)^{1/2}}{\left[1+\tilde{\mu}_p^2 H^2 + bc\left(1+\frac{\tilde{\mu}_p^2 H^2}{b^2}\right)\right]^{1/2}}, \qquad (2)$$

hold. $\tilde{\mu}$ denotes the Hall mobility of the carriers, φ_n and φ_p are the kinetic integrals, c the electron-to-hole concentration ratio, τ the relaxation time, S_1 the recombination rate on an illuminated surface, I_o the number of quanta incident per cm^2, l_d the electron diffusion length,

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Photomagnetic effect in p-type ...

b the electron-to-hole mobility ratio. In the photomagnetic effect the ratio between short-circuit current and photomagnetic emf is given by $V_{phm} = i_s l/d\sigma$, d is the thickness of the sample, l the distance between the contacts and σ the conductivity in the magnetic field. The quantity $\tau S_1/l_d$ was found to be between 0.01 and 0.1. For such small values the change in ambipolar diffusion length in the magnetic field from $V_{phm1}/V_{phm2} = 1+S_2\tau/l_d$. V_{phm1} is the photomagnetic emf of a specimen with illuminated etched surface, V_{phm2} the emf of the same specimen whose polished surface is illuminated. The results show that the theory of photomagnetic effect which is based on the solution of the kinetic current equation fits the experimental results better than a phenomenologic theory. For thin specimens

$$\frac{V_{phm1}}{V_{phm2}} = \frac{1 - \frac{1 - e^{-kd}}{kd}}{e^{kd} - \frac{1 - e^{-kd}}{kd}}. \qquad (13)$$

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B102/B138

Photomagnetic effect in p-type ...

holds. Hole concentration was measured as a function of acceptor concentration and was found to decrease with increasing p_1. For $p_1 \sim 10^{16} cm^{-3}$, μ_p was found to be 1700 $cm^2/v \cdot sec$ if the free-carrier concentration was assumed to be $1.8 \cdot 10^{16} cm^{-3}$. For μ_p theory yields 3600 $cm^2/v \cdot sec$. There are 6 figures and 14 references: 4 Soviet and 10 non-Soviet. The four most recent references to English-language publications read as follows: P. W. Kruse. J. Appl. Phys., 30, No. 5, 770, 1959; C. Hilsum, R. Barrie. Proc. Phys. Soc., 71, No. 460, 1958; R. N. Zitter, A. J. Strauss, A. E. Attard. Phys. Rev., 115, No. 2, 1959; C. Hilsum. Proc. Phys. Soc., 76, No. 489, 1960.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: May 18, 1961

Card 5/6

/61/003/011/025/056
/3104

24.7700 (1043,1055,1035)

AUTHORS: Komolova, T. I., Nasledov

TITLE: Study of static volt-ampere characteristics of rectifiers made of semiconductive titanium oxide

PERIODICAL: Fizika tverdogo tela, v. 3, 1961, 3400-3404

TEXT: The authors studied the static volt-ampere characteristics of rectifier elements at temperatures ranging from nitrogen temperature to +240°C, using a highly stable thermostat (a variant of K. Onnes' type). TiO_2 films, 20 by 20 mm, were produced on titanium plates previously polished, etched, and oxidized in water vapor at 800°C for 2 hr. Subsequently, they were cooled to 500°C in a furnace and further cooled in air to room temperature. As theory shows, the current strength must depend on voltage like

$$I = I_0(e^{qV/\beta kT} - 1),$$ where q = electron charge and

β = dimensionless coefficient. If $V \ll \beta kT/q$, this exponential function goes over into a linear one: $I = I_0(qV/\beta kT) \equiv G_0 V$, where G_0 denotes

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Study of static volt-ampere ... /003/0 /025/056 /B104

conductivity at zero voltage. Measurements ... on a great number of specimens always showed similar results. Fig. 1 shows volt-ampere characteristics for specimen no. 1 at ... different temperatures. The cutoff voltage and the resistance r_s were determined from similar curves for each temperature. The voltage V_{cutoff} which was 3.7-3.8 v at nitrogen temperature, decreased with rising temperature and amounted to 0.5-0.7 v at +240°C. The volume resistance ... be estimated from the inclination of the rectilinear section ... characteristic. Resistance increased from $4.5 \cdot 10^5$ ohm·cm² at nitrogen temperature to 5.35 ohm·cm² at + 240°C. r_s is an exponential function ... from which an activation energy of 0.16-0.18 ev is obtained. Another exponential section with high values of β appears on the direct ... the volt-ampere characteristic for TiO_2 rectifiers at low ... (0.2-0.5 ev). Owing to the existence of two exponential ... two values I_{01} and I_{02}, $(I_{01} \gg I_{02})$ follow for $\beta_1 \gg \beta_2$ from the ... $I = f(V) = I_0 e^{qV/\beta kT}$.

Fig. 4 shows the initial parts of the volt-ampere characteristics for specimen no. 1 at -79, +18, and +108°C. The first part of the inverse branch of the volt-ampere character... 2-3 v of the inverse

Card 2/6

30785
S/181/61/003/011/C25/056
B125/B104

Study of static volt-ampere ...

voltage, represents the current strength as a linear function of the voltage. The inclination of this straight line represents the conductivity of the rectifier at zero. From 2-3 v onward the above-mentioned linear function goes over into the exponential function $I_{inv} = I_{inv \cdot 0} \exp(\alpha V)$, where α is a temperature-dependent coefficient. The type of rectifier considered here behaves like other semiconductor rectifier. The rules established here can be described by the formulas of the theory of p-n junctions. The high values of V_{cutoff} agree with the large width of the forbidden band. There are 6 figures and 6 references: 1 Soviet and 5 non-Soviet. The three references to English-language publications read as follows: H. C. Gorton, T. S. Shilliday, F. K. Eggleston. Electr. Eng., 74, 10, 904, 1955. C. T. Sah, R. N. [illegible], W. Shockley. Proc. IRE, 45, 9, 1228, 1957. R. G. Breckenridge, [illegible] Hosler. Phys. Rev., 91, 793, 1953.

X

Card 3/4

30785
S/181/61/003/011/025/056
B125/B104

Study of static volt-ampere ...

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

X

SUBMITTED: June 13, 1961

Card 4/~~6~~4

S/181/61/003/011/026/056
B125/B104

AUTHORS: Mamayev, S., Nasledov, D. N., and Galabanov, V. V.

TITLE: Electrical properties of the semiconductive solid solutions $xCdSnAs_2 - y(2InAs)$

PERIODICAL: Fizika tverdogo tela, v. 3, no. 11, 1961, 3405-3413

TEXT: Electrical conductivity and Hall constant R were measured in the temperature interval of 77-950°K on 14 different compositions of the system $xCdSnAs_2 - y(2InAs)$. The measurements were made in a constant magnetic field of 6700 oe by a compensation method - in vacuo below room temperature, and above room temperature, in an argon atmosphere. Spectroscopically pure Cd, Sn, and In samples were used for the purpose. The compositions of the test samples (values x and y) are listed in the enclosed table. Figs. 1 and 2 show the electrical conductivity as a function of the reciprocal absolute temperature. In the interval of 77-280°K, the electrical conductivity of the samples is virtually independent of temperature; only the electrical conductivity of samples

Card 1/~~5~~ 3

S/181/61/003/011/026/056
B125/B104

5n1, 1n0, and 2n3 slowly decreases with increasing temperature. At high temperatures, from $\sim 350^{\circ}$K onward, σ increases exponentially for all the compositions examined here. The constancy of σ and R over a wide range of temperatures is indicative of a degeneracy at low temperatures. At high temperatures, the Hall constant decreases exponentially with increasing temperature. At low temperatures, the product (R,σ), which characterizes the carrier mobility, is virtually independent of temperature. It increases considerably with rising temperature above 250°K and decreases again above 600°K. The unvarying sign of R, which is characteristic of the test samples (except 1p99 and 1p399), is obviously due to the fact that, owing to the high impurity concentration in the samples, pure intrinsic conduction is not yet reached in the temperature range in question. The mobility ratio is almost equal to unity. At b = 1, R decreases exponentially (exponent $\Delta E/kT$) within the region of intrinsic conduction. If the order of magnitude of b is unknown, the error involved in the determination of ΔE from the R(T) curve may reach 100%. In this case, the value of ΔE obtained from $\sigma(T)$ is more exact. Fig. 8 contains values of ΔE as a function of the composition of the test samples. The values of ΔE obtained from R(T) and $\sigma(T)$ differ only slightly. The forbidden-band width of $CdSnAs_2$ is 0.26 ev. N. A. Goryunov is thanked for interest and advice. There are 8 figures and 9 references: 5 Soviet and 4 non-Soviet. The three references to English-language publications read as follows: A. I. Strauss, A. I. Rosenberg. Bull. Americ. Phys. Soc., 5, 83, 1960; A. I. Strauss, A. I. Rosenberg. I. Phys. Chem. Sol., 17, 278, 1961; H. Ehrenreich. Phys. Rev., 120, 6, 1951, 1960.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: June 13, 1961

Table. Electrical properties of the samples.
Legend: (1) number of sample; (2) type of conduction; (3) and (4) composition; (5) mobility; (6) conductivity.

BAKAYEV, A.V.; GELLER, I. Kh.; DORIN, V.A.; ZAKHAROV, M.P.; NASLEDOV, D.N.; SOLOV'YEV, R.A.

Method for investigating potential distribution in selenium rectifying cells. Zav.lab. 27 no.10:1240-1242 '61. (MIRA 14:10)

1. Leningradskiy politekhnicheskiy institut im. M. I. Kalinina.
(Selenium—Electric properties)

NASLEDOV, D.N., prof.

Semiconductors in science and technology. Vest. AN SSSR 31 no.11: 85-87 N '61. (MIRA 14:11)

(Semiconductors)

33350
S/181/62/004/001/019/0?-
B108/B104

9.4177 (1035, 1482)
9.4178
26.2421

AUTHORS: Nasledov, D. N., and Smetannikova, Yu. S.

TITLE: Temperature dependence of the carrier life-time in indium antimonide

PERIODICAL: Fizika tverdogo tela, v. 4, no. 1, 1962, 110 - 1..

TEXT: The temperature dependences of carrier lifetime and diffusion length in p- and n-type indium antimonide with impurity concentrations of 10^{13} - 10^{15} cm^{-3} have been studied in the interval of 90 - 180°K. The carrier lifetimes were determined from the photomagnetic and the photoelectric current by a method suggested by S. Kurnick et al. (J. Appl. Phys. 27, 278, 1956). Equilibrium carrier concentration and mobility data were determined from measurements of Hall constant and electrical conductivity. The specimens were InSb single crystals purified by zone melting and polished by etching. The lifetimes determined from photoconductivity and from the photomagnetic effect, i. e., electron and hole lifetimes, were different, particularly at low temperatures. This is explained by the trapping of nonequilibrium minority carriers, particularly in p-type speci-

X

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mens. A zone model with two recombination levels in the forbidden band is suggested. The trapping cross section for electrons and holes in this model are $\sigma_n \simeq 10^{-16}$ and $\sigma_p \simeq 10^{-13}$ cm^2, respectively. There are 9 figures, 3 tables, and 14 references: 3 Soviet and 11 non-Soviet. The four most recent references to English-language publications read as follows: R. Zitter et al. Phys. Rev., 115, 266, 1959; C. Hilsum Proc. Phys. Soc. 73, 81, 1959; R. Zitter. Phys. Rev., 112, 852, 1958; R. T. Lanisberg, A. R. Beattie. J. Phys. Chem. Sol., 8, 73, 1959.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: July 12, 1961

Card 2/2

34244

24.7600 (1035, 1043, 1164)

S/181/62/004/002/039/0..
B102/B138

AUTHORS: Yemel'yanenko, O. V., Kesamanly, F. P., and Nasledov, D. N.

TITLE: Thermomagnetic Nernst-Ettingshausen effects in degenerate indium antimonide

PERIODICAL: Fizika tverdogo tela, v. 4, no. 2, 1962, 546-548

TEXT: The temperature dependence of the longitudinal and the transverse Nernst-Ettingshausen effects was investigated in weakly and strongly degenerate InSb single crystals in the range 100 - 600°K. In+Sb were mixed in stoichiometric ratio, melted and doped with Se; the Czochralski method was used to grow electrically homogeneous single crystals with an electron concentration of 10^{16} - 10^{19} cm^{-3}. The crystals measured had the following characteristic parameters at room temperature:

X

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Thermomagnetic Nernst-Ettingshausen ...

number of specimen	17n	13n	7n
electron concentration	$4\cdot10^{16}$	$3\cdot10^{17}$	$6\cdot10^{18}$ cm^{-3}
mobility	60,000	40,000	6000 cm^2/v sec
degeneracy	0	+4	+14
linearity of N-E effects up to	800	1500	10,000 oe
measurement of temperature dependence of N-E effects	600	1000	4000 oe

13n and 7n had impurity conductivity, 17n - mixed conductivity. Since the hole mobility and the role of the holes in the thermomagnetic effect was much smaller than that of the electrons, the theory of pure impurity conductivity was applicable for all specimens. The results show that for InSb, as for InAs, at higher temperatures the electrons are mainly

Card 2/4

scattered from acoustic lattice vibrations ($Q^{\perp}$, $Q^{\parallel}>0$). Lattice scattering increases with the degree of degeneracy. There are 2 figures and 9 references: 7 Soviet-bloc and 2 non-Soviet bloc. The reference to the English-language publication reads as follows: H. Ehrenreich. J. Phys. Chem. Sol. 2, 131, 1957.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad). Institut fiziki AN Az. SSR Baku (Institute of Physics AS Azerbaydzhanskaya SSR, Baku)

SUBMITTED: September 13, 1961

Fig. 1. Temperature dependence of $Q^{\perp}$ for 17n (1), 13n (2) and 7n (3).

Fig. 2. Temperature dependence of $Q^{\parallel}$ for 17n (1), 13n (2), and 7n (3). $Q^{\parallel}$ and $Q^{\perp}$ given in CGSM units.

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24.7600

36478
S/181/62/004/003/018/045
B152/B102

AUTHORS: Zotova, N. V., and Nasledov, D. N.

TITLE: Galvano- and thermomagnetic properties of p-type indium arsenide

PERIODICAL: Fizika tverdogo tela, v. 4, no. 3, 1962, 681 - 684

TEXT: The authors measured the coefficient $Q^{\perp}$ of the transverse Nernst-Ettingshausen effect, the hole mobility, and the Hall constant R of p-type InAs. The results showed that in the range 95-350°K the carrier scattering from impurity ions passes over into scattering from phonons. The crystals (specimen 1(+Zn): $p = 1.8\cdot10^{18}$, specimen 2(+Cd): $p = 2.6\cdot10^{18}$, specimen 3 (+Zn): $p = 2.8\cdot10^{19}$ cm^{-3}) were produced by doping n- type InAs with Zn or Cd of a purity $\gg$ 99.99%. The carrier mobility measured decreased with increasing temperature, but more slowly than according to the $T^{-3/2}$ law which holds for pure scattering from acoustic lattice vibrations. The Nernst-Ettingshausen effect must be negative for scattering from

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impurity ions, positive for scattering from phonons. For specimens 1 and 2 in the temperature range investigated, $Q^{\perp}$ first tends to positive values, but then assumes high negative values due to the mixed conductivity occurring at 300 - 350°K. From $1 - r = 2.32 \cdot 10^4 Q^{\perp} K(\mu)/u_H$ (μ - reduced Fermi level, $K(\mu)$ - factor taking account of the degeneracy of the carrier gas, u_H - Hall mobility of the holes), the effective exponent of $l \sim v^r$ can be calculated, where l - mean free path of the carriers, v - their thermal velocity. r = 4 for scattering from ions, r = 0 for scattering from phonons. The measurements showed a decrease of r with increasing temperature. The authors calculated the effective mass of the holes from the differential thermo-emf ($\alpha = k/e \cdot [(r/2+2)F_{r/2+1}(\mu)/(r/2+1)F_{r/2}(\mu) - \mu]$, and from the known hole concentration $p = (m_p^*/m)^{3/2}(4/\sqrt{\pi})(2\pi mkT/h^2)^{3/2}F_{1/2}(\mu)$, ($F(\mu)$ - Fermi integral) the effective hole mass m_p^* can be calculated. m_p^* decreases with increasing temperature; in specimen 3 with the strongly degenerate hole gas, it is much greater than in specimens 1 and 2. O. V.

Card 2/3

S/181/62/004/003/018/045
B152/B102

Galvano- and thermomagnetic ...

Yemel'yanenko is thanked for discussions. There are 4 figures, 2 tables, and 5 references: 3 Soviet and 2 non-Soviet. The reference to the English-language publication reads as follows: C. Hilsum, A. G. Rose-Innes, Semiconducting III-V Compounds. Pergamon Press N. Y.-London-Paris, 1961.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: November 3, 1961

Card 3/3

9,4370

S/181/62/004/004/021/042
B104/B108

AUTHORS: Zolotarev, V. F., and Nasledov, D. N.

TITLE: Dependence of the bipolar diffusion length and of the sum of the Hall mobilities of the carriers in p-type InSb on the magnetic field strength at room temperature

PERIODICAL: Fizika tverdogo tela, v. 4, no. 4, 1962, 977 - 982

TEXT: Samples were cut perpendicularly to the direction of crystal growth (5·1.5·0.3 mm). They were polished mechanically on one side, and electrolytically on the other. The photomagnetic emf was determined with illumination from both sides separately. The Hall coefficient of the samples examined at 190°K was between 5.45 and 175,000 cm^3/Coulomb; the acceptor concentration was between $3.6\cdot10^{13}$ and $1.7\cdot10^{18}$ cm^{-3}, and the Hall coefficient at room temperature was between -350 and + 3.6 cm^3/Coulomb. It is concluded from experimental and theoretical results regarding the Hall mobility of carriers in a magnetic field in different scattering

Card 1/2

Dependence of the bipolar diffusion ... S/181/62/004/004/021/042
B104/B108

processes that the carriers are scattered from polar lattice vibrations, from impurity ions, from free carriers, and from acoustic vibrations. It was not possible to estimate the quantitative contributions of the various scattering mechanisms. There are 6 figures and 1 table.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR, Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: December 1, 1961

Card 2/2

36898
S/181/62/004/004/038/042
B102/B104

24.6111
27.7000

AUTHORS: Nasledov, D. N., Rogachev, A. A., Ryvkin, S. M., and Tsarenkov, B. V.

TITLE: Recombination radiation of gallium arsenide

PERIODICAL: Fizika tverdogo tela, v. 4, no. 4, 1962, 1062-1065

TEXT: Monocrystalline n-type InAs plates with an electron concentration of $\leqslant 10^{17} cm^{-3}$ were used to study the intrinsic recombination radiation. A p-n junction of ≈ 0.1 cm^2 was produced by diffusion of Zn or Cd into the InAs plate. The nonequilibrium carriers were excited by pulsed injection through the junction. The radiation was observed in parallel to the p-n junction plane. At $77^{\circ}K$ the emission spectrum has a narrow peak at 1.47 ev (optical self-absorption edge) and two maxima at lower energies which are in connection with recombination via impurity levels. One of these levels is 0.2 ev distant from the middle of the forbidden band, the other 0.25 ev from a band edge. The relative height of all maxima depends on the current density through the p-n junction. At less

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Recombination radiation of gallium ... S/181/62/004/004/038/042 B102/B104

than 1 a/cm^2 only impurity radiation is observed, then intrinsic radiation arises and increases rapidly, and between 10 and 100 a/cm^2 the relative height of the maxima remains constant. The results can be explained by assuming volume-charge recombination at weak currents and injection at high currents. At above 10 a/cm^2 the emission intensity increases linearly with the current density through the p-n junction and decreases only above $\sim 10^3$ a/cm^2. The forbidden band width is temperature-dependent according to the law $(1.51-5.6\cdot 10^{-4}T)$ ev. The intrinsic emission line narrowing observed at high current densities can be explained by inverse band filling (production of states with "negative temperature") or by assuming that the injected carriers cause degenerate filling of one band only. The latter possibility is more probable. There are 2 figures.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR, Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: January 11, 1962

Card 2/2

37933

S/181/62/004/005/022/055
B125/B108

26.2420
9.4177

AUTHORS: Mikhaylova, M. P., Nasledov, D. N., and Slobodchikov, S. V.

TITLE: Photomagnetic effect and photoconductivity in InP

PERIODICAL: Fizika tverdogo tela, v. 4, no. 5, 1962, 1227-1232

TEXT: The photomagnetic effect and the photoconductivity of n-type InP are investigated at 100-300° K for carrier concentrations of $n=8.4\cdot10^{16}$ to $2\cdot10^{17}$ cm^{-3} at 300° K. The photoelectromotive force at 300° K up to ~8000 oe increases linearly with the magnetic field strength. The photomagnetically induced photoelectromotive force of an electron semiconductor with impurities is $V_{pm} = I_0HL(1/tn_1)$ with $L = \sqrt{D\tau_{pm}}$. The photoconductivity is then $V_{pc} = I_0E\tau_{pc}(1/tn_1)$. l and t denote length and thickness of the sample, D is the diffusion constant. The lifetimes τ_{pm} and τ_{pc} are to be determined from photomagnetic effect and photoconductivity, respectively. The photoelectromotive force decreases with decreasing temperature. At the same time, photoconductivity increases

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by more than ten times. It decreases at modulation frequencies of ~100 cycles. The electron lifetime at 300°K is $1.7\cdot10^{-3}$-$2.2\cdot10^{-3}$ sec, that of the minority carriers is $2\cdot10^{-6}$ - $2.5\cdot10^{-7}$ sec. The diffusion length of the holes increases with increasing temperature. This temperature dependence is caused by the decrease of the hole lifetime with decreasing temperature. The electron lifetime increases with subsiding temperature. There are 5 figures. The most important English-language reference is: C. Hilsum, B. Holeman. Proceedings International Conference on Semiconductor Physics. Prague, 1960.

ASSOCIATION: Fiziko-tekhnicheskiy institut imeni A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: December 26, 1961

37945

126.2490

9.4177

S/181/62/004/005/043/055
B101/B108

AUTHORS: Gutkin, A. A., and Nasledov, D. N.

TITLE: The dependence of the long-wave limit of the photo-effect in p-n junctions of GaAs on the electric field

PERIODICAL: Fizika tverdogo tela, v. 4, no. 5, 1962, 1360 - 1363

TEXT: The variation of the photocurrent from GaAs crystals under the action of a strong electric field was investigated. The long-wave edge of the spectral characteristic was determined for a GaAs photo-diode with p-n junction. Results: (1) In the photon-energy range of 1.39 - 1.415 ev, the spectral characteristic is parallel to the curve for the absorption coefficient $k = f(\hbar\omega)$ (cf. T. S. Moss. J. Appl. Phys., 38, 2136, 1961) in the absence of an electric field. (2) When $\hbar\omega$ is less than 1.39 ev, the spectral characteristics for various voltages in the back direction begin to diverge. Hence, k becomes a function of the field strength. It was found that $I_{ph} = \int_{-W/2}^{+W/2} k dx$ when $k \ll 1/W$. Here, I_{ph} is the

Card 1/2

The dependence of the...

S/181/62/004/005/043/055
B101/B108

photo-current, W is the width of the space-charge region (= crystal), x is the coordinate counted from the center of the space charge. (3) The probability $\alpha(\omega)$ of quantum absorption was calculated from $\alpha(\omega) = [AE^2/m_{\parallel}\omega(\varepsilon_0-\hbar\omega)^{5/2}]\exp[-(4\sqrt{2m_{\parallel}}/3e\hbar E)(\varepsilon_0-\hbar\omega)^{3/2}]$, where E is the field strength, A is a constant, $m_{\parallel}$ is the reduced mass of the carrier pairs, and ε_0 is the forbidden band width. Assuming $m_n = 0.07\ m_0$, $m_p = 0.6\ m_0$, and $\varepsilon_0 = 1.38$ ev qualitative agreement with experimental data was obtained. (4) If $\hbar\omega\sim\varepsilon_0$, carriers excited by light in regions where $E = 0$ make large contributions to the photo-current. There are 2 figures.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR (Physicotechnical Institute imeni A. F. Ioffe, AS USSR) Leningrad

SUBMITTED: January 19, 1962

Card 2/2

24770

S/181/62/004/006/047/051
B108/B138

AUTHORS: Vinogradova, K. I., Galavanov, V. V., and Nasledov, D. N.

TITLE: Dependence of carrier mobility on the impurity concentration in InSb crystals

PERIODICAL: Fizika tverdogo tela, v. 4, no. 6, 1962, 1673 - 1674

TEXT: The authors studied this problem as little information has been available. Measurements were made at 77 and 300°K. The hole mobilities at both temperatures are virtually the same; they decrease with increasing impurity concentration. Electron mobility decreases slightly with increasing impurity concentration at 77°K. At 300°K it remains constant up to 10^{16} cm^{-3}, but at higher concentrations it decreases and approaches the same value as at 77°K. At low temperatures mobility is chiefly determined by the scattering of electrons from holes and phonons. There are 2 figures.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

Card 1/2

ZOLOTAREV, V.F.; NASLEDOV, D.N.

Photomagnetic emf in p-type indium antimonide at room temperature in a variable magnetic field. Fiz.tver.tela 4 no.7:1952-1956 Jl '62. (MIRA 16:6)

1. Fiziko-tekhnicheskiy institut imeni A.F.Ioffe AN SSSR, Leningrad.

(Indium antimonide) (Photomagnetic effect)

GUTKIN, A.A.; NASLEDOV, D.N.; SEDOV, V.Ye.; TSARENKOV, B.V.

Photoelectric properties of GaAs p-n junctions. Fiz. tver. tela 4 no.9:2338-2348 S '62. (MIRA 15:9)

1. Fisiko-tekhnicheskiy institut imeni A.F. Ioffe AN SSSR, Leningrad.

(Junction transistors) (Gallium arsenide)
(Photoelectricity)

ZOLOTAREV, V.F.; NASLEDOV, D.N.

Photogalvanomagnetic phenomena in InSb at room temperature. Fiz. tver. tela 4 no.9:2567-2575 S '62. (MIRA 15:9)

1. Fiziko-tekhnicheskiy institut imeni A.F. Ioffe AN SSSR, Leningrad.
(Hall effect) (Indium antimonide)

44134

S/181/62/004/010/018/063
B108/B104

24.7700

AUTHORS: Nasledov, D. N., and Slobodchikov, S. V.

TITLE: The electrical properties of GaP crystals

PERIODICAL: Fizika tverdogo tela, v. 4, no. 10, 1962, 2755 - 2759

TEXT: The variation of the conductivity and of the Hall constant of n-type and p-type GaP single crystals with temperature was studied in the range between 78 - 100°K and room temperature. The conductivity and the Hall effect were measured by the usual potentiometric compensation method. The n-type samples had a carrier concentration of about $2\cdot10^{17}$ cm^{-3}, the p-type samples had one of $\sim 1.2\cdot10^{18}$ cm^{-3}, and the partially compensated p-type samples one of $\sim 4\cdot10^{17}$ cm^{-3}. The ionization energy of the donor impurities as estimated from the temperature dependence of the Hall constant was of the order of 10^{-2} ev. The variation with temperature of the electron mobility shows that the latter is limited by the scattering from impurity ions at low temperatures. The rapid decrease at higher temperatures (> 150°K) can be explained by the dominant scattering from polar

Card 1/2

lattice vibrations. An estimate of the electron effective mass gave $m_n^* = 0.65m_0$. As temperature decreases, a considerable change in resistivity of partially compensated p-type GaP in a magnetic field can be observed. $\frac{\Delta\varrho}{\varrho_0}$ is proportional to H^2 within the range of 1000 - 8000 oe. The results show that polar lattice vibrations can play a significant part in the mechanism of carrier scattering, in particular for pure and for compensated GaP of low conductivity. There are 7 figures.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR, Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: May 17, 1962

NASLEDOV, D.N.; SLOBODCHIKOV, S.V.

Photoconductivity in GaP. Fiz. tver. tela 4 no.11:3161-3164 N '62. (MIRA 15:12)

1. Fiziko-tekhnicheskiy institut imeni A.F. Ioffe AN SSSR, Leningrad.
(Photoconductivity) (Gallium phosphide)

~~NASLEDOV, D.N.~~; ROGACHEV, A.A.; RYVKIN, S.M.; KHARTSIYEV, V.Ye.;
TSARENKOV, B.V.

Structure of direct recombination spectra of gallium arsenide. Fiz. tver. tela 4 no.11:3346-3348 N '62.
(MIRA 15:12)

1. Fiziko-tekhnicheskiy institut imeni A.F. Ioffe AN SSSR, Leningrad.

(Gallium arsenide—Spectra)

GUTKIN, A.A.; NASLEDOV, D.N.; SEDOV, V.Ye.; TSARENKOV, B.V.

Photoelectric solar energy converters using GaAs.
Radiotekh. i elektron. 7 no.12:2095-2096 D '62.
(MIRA 15:11)

1. Fiziko-tekhnicheskiy institut im. A.F. Ioffe AN SSSR.
(Photoelectric cells)
(Solar batteries)

S/030/62/000/003/007/007
B102/B138

AUTHOR: Nasledov, D. N., Professor

TITLE: New semiconductor materials

PERIODICAL: Akademiya nauk SSSR. Vestnik, no. 3, 1962, 87 - 89

TEXT: The conference convened by the Fiziko-tekhnicheskiy institut im. A. F. Ioffe Akademii nauk SSSR (Physicotechnical Institute imeni A. F. Ioffe of the Academy of Sciences USSR) was held in Leningrad from 18. - 23. December 1961. It was devoted to the exchange of information on the production and properties of new semiconductor materials. It was attended by over 300 scientists who read papers on, and discussed, the production and study of semiconductors in the Soviet Union during the last 2 - 3 years. Most of the new semiconductor materials mentioned were multicomponent chemical compounds, with those between elements of the 3rd and 5th groups playing a central part. The antimonides and arsenides of indium and gallium seemed to show particular promise for the future. GaAs has been found very suitable for diodes operating at high temperatures and those with pulse durations of up to

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New semiconductor materials

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10^{-9} sec. InAs and InSb have been used for sensitive Hall generators, photoelectric cells, photoresistors etc. These compounds are obtained as homogeneous, pure, single crystals. A number of papers were devoted to the investigation of the properties of this kind of semiconductor, with particular attention to structural defects and their effects. Besides lead compounds and multicomponent solid solutions, reports were also read on silicon carbide semiconductors which are highly suitable for apparatus with p-n junctions operating at high temperatures. Oxide semiconductors appear to be particularly important for industry, especially for temperature measurement and control. Motions were carried to the effect that semiconductor research should be intensified, especially in the sphere of energy spectra in a wide temperature range, carrier scattering, doping methods and the production of high-purity single crystals. New semiconductor devices should also be developed.

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L 04741-67 EWT(l)/EWT(m)/EWP(t)/ETI IJP(c) AT/JD

ACC NR: AP6024472 SOURCE CODE: UR/0181/66/008/007/2098/2103

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63
B

AUTHOR: Imenkov, A. N.; Kozlov, M. M.; Nasledov, D. N.; Tsarenkov, B. V.

ORG: Physicotechnical Institute im. A. F. Ioffee, AN SSSR, Leningrad (Fiziko-tekhnicheskiy institut AN SSSR)

TITLE: Kinetics of radiative recombination of nonequilibrium carriers in GaAs p-n junctions

27 21

SOURCE: Fizika tverdogo tela, v. 8, no. 7, 1966, 2098-2103

TOPIC TAGS: gallium arsenide, radiative recombination, semiconductor carrier, pn junction, relaxation process, spectral distribution, radiation intensity

ABSTRACT: The authors report results of experiments on the dependence, on the current density, of the intensity of radiation for different bands of the spectrum (photon energy range 0.7 - 1.5 ev) of GaAs diffusion p-n junctions, at 77 and 293K, and also results of a simultaneous investigation of the relaxation of the radiation intensity when rectangular current pulses are passed through the junction. The relaxation study is a continuation of earlier work by the authors (Abstracts of Papers of Second All-Union Conference on p-n Junctions, AN LatSSR, Riga, 1964, p. 14) where a long-wave aftereffect was noted after the termination of a square pulse. The GaAs p-n junctions were obtained by diffusion of Zn, Cd, or Cd and Mn jointly. The tests consisted of determining the spectral distribution of the radiation intensity, the variation of the radiation intensity with the current, and oscillograms of the current, voltage, and

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radiation-intensity pulses. The current pulses ranged in amplitude from 0.05 to 7 amp and in duration from 10 to 100 μsec. Pulses with duration ~10 nsec were also used. The spectrum consisted of several bands, the presence of which indicates that the recombination of the nonequilibrium carriers goes in part through deep levels. The possible kinetics of such a process are discussed. The current and voltage relaxation time is several orders of magnitude shorter than the intensity relaxation time of the long-wave radiation. The bands with longer wavelength have longer relaxation times. The two ban-s with the longest wavelength are attributed to recombination of the minority carriers injected over the potential barrier and captured at deep levels. The authors thank O. V. Konstantinov, V. I. Perel', and A. L. Efros for a discussion of the results. Orig. art. has: 4 figures.

SUB CODE: 20/ SUBM DATE: 11Dec65/ ORIG REF: 002/ OTH REF: 002

Card 2/2 *ab*

Galvanomagnetic properties of indium antimonide doped with elements from the first and second groups, in the temperature interval 4.2 to 300°K. K. I. Vinogradova, D. N. Nasledov, Yu. G. Popov, Yu. S. Smetannikova.

Electrical properties of doped crystals of indium antimonide in a wide range of temperatures and impurity concentration. V. V. Galavanov, D. N. Nasledov, A. S. Filipchenko.
(Presented by V. V. Galavanov--15 minutes).

Report presented at the 3rd National Conference on Semiconductor Compounds, Kishinev, 16-21 Sept 1963

Report presented at the 3rd National Conference on Semiconductor Compounds, Kishinev, 16-21 Sept 1963

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2. Electrical properties of highly degenerate crystals of n- and p-type gallium arsenide. O. V. Yemel'yanenko, F. P. Kesamaniy, D. N. Nasledov, V. G. Sidorov, G. N. Talalakin.

Concerning the interaction of electrons with lattice vibrations in gallium arsenide. O. V. Yemel'yanenko, T. S. Lagunova, D. N. Nasledov, V. Ye. Shcherbatov.

Electrical properties of gallium arsenide with different impurities. D. N. Nasledov, G. N. Talalakin.

Investigation of the properties of impurity zones in crystals of p-type gallium arsenide. O. V. Yemel'yanenko, T. S. Lagunova, D. N. Nasledov, V. Ye. Shcherbatov.

Galvanomagnetic properties of indium arsenide in a wide temperature range. Yu. M. Burdukov, I. V. Zatova, T. S. Lagunova, D. N. Nasledov.

Nernst effect in n-type indium phosphide.
F. P. Kesamanly, E. E. Klotin'.
(Presented by O. V. Yemel'yanenko--25 minutes).

S/139/63/000/001/012/027
E202/E420

AUTHORS: Bakayev, A.V., Geller, I.Kh., Dorin, V.A., Zakharov, P.M., Nasledov, D.N., Solov'yev, R.A.

TITLE: Distribution of potential in selenium rectifying elements between electrodes

PERIODICAL: Izvestiya vysshikh uchebnykh zavedeniy. Fizika, no.1, 1963, 78-84

TEXT: Results of measuring potential distribution in selenium rectifying elements in the conducting direction are described. To explain in detail the mechanism of potential distribution between the electrodes, measurements were carried out at points separated by a distance of 5 μ. Since the thickness of selenium layer varies from 50 to 100 μ it was necessary to measure the potential at 10 to 20 points. In order to carry out the measurements the layer of selenium and the p-n junction region were stripped and a transverse section prepared. Both types of rectifiers, i.e. those with p-n junction between the upper electrode and the layer of selenium, and those in which the p-n junction lies between the layer of selenium and the base, were investigated. The method was based on
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measuring the difference of potential between one of the electrodes and a probe, the latter being placed at various points on the surface of the transverse section of the element. A special instrument incorporating a microhardness gauge of the diamond pyramid type in which the latter was replaced by a steel wedge-shaped probe was used. During measurements the probe was pressed into the selenium in order to obtain reliable results. The width of the indentation made by the probe was 1.5 to 2 μ, hence the potential could be measured at points separated by a distance of 5μ. Since the probe contact with selenium has a considerable resistance of the order of 10^8 to 10^9 ohms, a high resistance voltmeter was used in the measurements. This comprised a potentiometer with a center zero electrometer sensitive to a current of 10^{-11} A. The measurements had an absolute error of 0.001 V. Considerable care was taken in the preparation of the transverse sections. The results have shown that the main fraction of the potential applied to the element in the conducting direction falls over the p-n junction region, on the other hand the layer of selenium accounts for not more than 25% of the above fall. In addition to plotting

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Distribution of potential ...

the potential against the distance over the CdS-(orCdSe)-Se-Bi_2Se_3-Al portions of the sandwich, preliminary volt-ampere characteristics of both types of rectifier were measured on polished and unpolished samples. There are 6 figures.

ASSOCIATION: Leningradskiy politekhnicheskiy institut imeni M.I.Kalinina (Leningrad Polytechnic Institute imeni M.I.Kalinin)

SUBMITTED: August 22, 1961

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S/181/63/005/001/024/064
B102/B186

AUTHORS: Nasledov, D. N., Mamayev, S., and Yemel'yanenko, O. V.

TITLE: Investigation of the thermo-emf and the thermomagnetic effects in alloys of the system $CdSnAs_2-2InAs$

PERIODICAL: Fizika tverdogo tela, v. 5, no. 1, 1963, 147-150

TEXT: The authors continue previous investigations (FTT, 2, 176, 1960; 3, 3405, 1961; DAN SSSR, 142, 623, 1962) of the system $CdSnAs_2-2InAs$ whose initial components are characterized by a particularly high carrier mobility (>15,000-20,000 $cm^2/v \cdot sec$). In the range 0-50% InAs the alloys have chalcopyrite structure and above 50% InAs sphalerite structure; below 75% InAs they are n-type, above this they are p-type. The thermo-emf and the thermomagnetic Nernst-Ettingshausen effects were measured by a method described in PTE, No. 1, 98, 1960, applying weak magnetic fields ($uH/c \ll 1$). In $CdSnAs_2$, InAs, the Nernst-Ettingshausen effects ($Q^{\perp}$, $Q^{\parallel}$), thermo-emf (α), mobility (u) and Hall effect (R) were measured in the

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range 100-600°K. For $CdSnAs_2$ and InAs the temperature dependences of the effects were similar: At low temperatures $Q^{\parallel}$ and $Q^{\perp}$ were negative, changed sign between ~300-400°K and reached maxima at ~600°K. u decreased slowly with increasing temperature and dropped to 6000 cm^2/v.sec. R remained almost constant, α was always negative, |α| increased with temperature. The negative sign of Q at low temperature is indicative of carrier scattering from impurity ions; r from the $l \sim v^r$ law is 2. The positive sign at higher temperatures is attributed to carrier scattering from acoustic phonons (r = 0.0 - 0.3). Here l is the mean free path and v the velocity of the carriers (electrons). Corresponding measurements of $2CdSnAs_2\cdot(2InAs)$ and $CdSnAs_2\cdot(2InAs)$, having electron concentrations of $1.7\cdot10^{18}cm^{-3}$ and $4\cdot10^{18}cm^{-3}$ at room temperature, were made in the range 100-700°K. For both alloys $Q^{\parallel}$ and $Q^{\perp}$ were positive in the whole range with maxima at high temperatures. u and R of the first alloy remained almost constant, u of the second one had a distinct maximum at T ≳ 600°K (~2000 cm^2/v.sec) where R dropped. For both r = 0.3 - 0.9 in the whole temperature range The effective carrier mass was always small and almost independent of composition; its most probable value was $\sim 0.045\ m_o$. There are 4 figures and 1 table.

ASSOCIATION: Fiziko-tekhnicheskiy institut im. A. F. Ioffe AN SSSR, Leningrad (Physicotechnical Institute imeni A. F. Ioffe AS USSR, Leningrad)

SUBMITTED: July 23, 1962

NASLEDOV, D N

AID Nr. 975-15 23 May

NONLINEAR PHOTOEFFECT OF GaAs p-n JUNCTIONS (USSR)

Gutkin, A. A., D. N. Nasledov, and V. Ye. Sedov. Fizika tverdogo tela, v. 5, no. 4, Apr 1963, 1138-1142. S/181/63/005/004/027/047

Two types of GaAs photodiodes were studied. The specimens were obtained by diffusion of acceptor-type dopants into n-type material with a carrier concentration of $\doteq 10^{17}$ cm^{-3} and a carrier mobility of ~ 3200 cm^2/v·sec. The p-region of the first type of sample was ~ 10 μ thick after diffusion and was decreased by etching in a boiling mixture (5NaOH (5%) + 1 H_2O_2 (30%) + 24H_2O) to ~ 1 μ. The p-region of the second type was 1 μ thick after diffusion and the specimens were not etched. Diffusion conditions were designed to produce a dopant-atom concentration of ~ 10^{18} cm^{-3} at the surface of the samples. Photocurrent characteristics, dependence of photosensitivity on bias light intensity, spectral distribution of photosensitivity with constant-spectrum bias light, dependence of photosensitivity on bias light wavelength, and spectral distribution of photosensitivity with a constant electric field applied to the illuminated p-surface were obtained. Specimens of the first type

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NONLINEAR PHOTOEFFECT [Cont'd] S/181/63/005/004/027/047

had nonlinear photocurrent characteristics and exhibited increased photosensitivity with an increase in bias-light intensity. The nonlinear properties of the first type of diode are attributed to light-induced changes in the recombination rate at the illuminated p-surface. Specimens of the second type had linear photocurrent characteristics, and exhibited no dependence of photosensitivity on bias light. [BB]

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